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EFFECT OF IONIZING RADIATION ON PHYSICAL AND CHEMICAL PROPERTIES OF FIBERBOARD AND PAPERBOARD

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13. ABSTRACT

In a large-scale production of prepackaged radappertized (irradiation sterilized) foods there are advantages in performing the irradiation of filled metal cans or flexible packages while stacked in fiberboard or paperboard shipping containers. This study was performed to determine the effect of electron and gamma radiation on the physical and chemical properties and functional performance of the fiberboard and paperboard materials that are used in the packing of cans and flexible packages of radappertized foods. Electron and gamma radiation caused significant physical and chemical changes in the fiberboard and paperboard materials. Physical property values (puncture, burst, tear, tensile) decreased with increasing radiation dose (1, 3, and 6 megarads) and increasing irradiation temperature (-80°C, -30°C, and 21°C). Whereas the component testing of fiberboard and paperboard and laboratory drop tests of fiberboard containers indicated that irradiation at a food-sterilization dosage level caused marked reductions in performance of the materials and containers made therefrom, these changes were not great enough to seriously impair the functional performance of the fiberboard and paperboard containers for packing of cans or packages of food during irradiation processing and subsequent shipment and storage.

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Intrinsic Viscosity			7			
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Tensile Strength			7			
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Materials			7			
Tests			8			
Drop Tests			10			
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FOREWORD

The work covered by this report was performed under Project 1J662713A033, Radiation Preservation of Food, Task – Basic Food Irradiation Research: Packaging and Packing of Irradiation Sterilized Meat Products.

In a large-scale production of prepackaged radappertized (irradiation-sterilized) foods there are advantages in performing the irradiation of metal cans or flexible packages while in the shipping container, either fiberboard or paperboard containers. The work covered in this report represents an investigation to determine the effect of electron and gamma radiation on the chemical and physical properties of fiberboard and paperboard materials and to evaluate the performance of shipping containers during the irradiation processing and subsequent shipment and storage. The investigations described were performed by Messrs. John J. Killoran and Peter T. Burke of the General Equipment & Packaging Laboratory, U.S. Army Natick Laboratories and Mr. Sheo Ran Agarwal, now at Bhabha Atomic Research Centre, B & BT Division, Bombay 85, India. Mr. Agarwal was a visiting scientist at the U. S. Army Natick Laboratories during the period February to December, 1969, on a National Academy of Sciences–National Research Council fellowship sponsored by the International Atomic Energy Agency, Vienna, Austria.

TABLE OF CONTENTS

	Page
Introduction	5
Results and Discussion	6
Component Testing of Fiberboard	6
Effect of Irradiation Temperature	11
Component Testing of Paperboard	11
Drop Test of Gamma Irradiated Boxes	17
Performance of Fiberboard and Paperboard in the Shipment and Storage of Radappertized Beef	19
Conclusions	21
Experimental	22
Literature Cited	25

LIST OF ILLUSTRATIONS

			Page
Figure	1.	Puncture Resistance of Irradiated Fiberboard	13
Figure	2.	Scoreline Failure of Irradiated Fiberboard	20

LIST OF TABLES

Table	I.	Effect of Gamma Radiation on Intrinsic Viscosity of Fiberboard	7
Table	II.	Effect of Gamma Radiation on Ply Separation of Wet Fiberboard	8
Table	III.	Effect of Gamma Radiation on Puncture Resistance of Fiberboard	9
Table	IV.	Effect of Gamma Radiation on Bursting Strength of Fiberboard	10
Table	V.	Effect of Irradiation Temperature on Puncture Resistance of Fiberboard	12
Table	VI.	Effect of Radiation and Irradiation Temperature on Bursting Strength of Fiberboard	14
Table	VII.	Effect of Gamma Radiation on Tensile Strength and Tear Resistance of Paperboard	16
Table	VIII.	Effect of Gamma Radiation on Performance of Fiberboard Containers	18

EFFECT OF IONIZING RADIATION ON PHYSICAL AND CHEMICAL PROPERTIES OF FIBERBOARD AND PAPERBOARD

Introduction

Primary efforts in the food irradiation program at the U.S. Army Natick Laboratories have been the application of radappertization (irradiation sterilization) to meats, poultry, and certain shellfish and fin fish. Proof of wholesomeness convincing to health authorities on the national level remains the major problem to be resolved before ionizing radiation can be used commercially for food sterilization. During 1971 and 1972, 70,308 kilograms (155,000 pounds) of beef was processed for a wholesomeness study.[1] This beef was enzyme-inactivated and then equally divided among four categories for further processing, i.e., frozen control beef, thermally sterilized beef, gamma irradiation sterilized beef, and electron-irradiation sterilized beef. Irradiation of the beef was performed at –30°C. Lowering the irradiation temperature to –30°C results in substantial improvement in acceptance of the food over that obtained for ambient temperature irradiation.[2] Because the irradiation of the beef takes place after the beef is vacuum packaged in a tinplate can for gamma radiation and in a flexible package for electron radiation, it has been convenient to irradiate packages of beef while they are in the shipping containers. This procedure eliminates the step of repacking after the irradiation sterilization of the beef. Normal practice has been to irradiate twelve cans (404 x 700) of beef in a fiberboard container and sixteen flexible packages of beef in a paperboard container.

This study was designed to determine the effect of electron and gamma radiation on the chemical and physical properties of fiberboard and paperboard materials and to evaluate the performance of shipping containers during the irradiation processing and subsequent shipment and storage.

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Results and Discussion

Component Testing of Fiberboard

Gamma Irradiation at 21°C

Intrinsic Viscosity: The intrinsic viscosity is a sensitive measure of the chemical changes that occur in cellulose upon exposure to ionizing radiation. Intrinsic viscosity and viscosity average molecular weight data for V3s fiberboard irradiated to 3 megarads (Mrad) and 6 megarads (Mrad) are shown in Table I. The 3-Mrad dose caused a reduction in viscosity average molecular weight from 3.42×10^5 to 8.0×10^4, and at 6 Mrad it was reduced to 5.1×10^4. These reductions are indicative of chain scission in the cellulose molecules of the fiberboard. It has been reported that a radiation dose of 1 Mrad resulted in a fracture of 0.16% of the bonds between glucose units in a cellulose molecule.[4,5].

Wet Ply Separation: The wet ply separation data for three fiberboard materials subjected to a dose of 6 Mrad of gamma radiation are shown in Table II. Irradiation had no observable effect on the ply or edge separation of the component plies of the V2s and V3s fiberboard materials. Irradiation caused complete separation of the corrugated medium and the liner material of the V3c material. Ply separation was estimated to be 30% for the nonirradiated V3c fiberboard and 100% for the irradiated fiberboard.

Puncture Resistance and Bursting Strength: Puncture resistance and bursting strength may be indicative of chemical changes in fiberboard exposed to ionizing radiation.[6] Puncture resistance data for five types of fiberboard that were irradiated to 3 Mrad and 6 Mrad and tested in the dry state are shown in Table III. Irradiation caused a reduction in the puncture resistance of the five materials. For example, at 3 Mrad the reduction in puncture resistance of V2s fiberboard was 12.1% at 6 Mrad the reduction was 21.5%.

Table IV shows the data obtained on the effect of gamma radiation on the bursting strength of five types of fiberboard that were tested in both the dry and wet states. Irradiation caused a reduction in the bursting strength of the five materials tested in the dry state, e.g., the reduction was 24.3% for the V2s fiberboard irradiated to 6 Mrad. The V2s and V3s irradiated fiberboards that were tested in the wet state also showed reductions in

Table I. Effect of Gamma Radiation on Intrinsic Viscosity of Fiberboard

Irradiation Dose* (Mrad)	Intrinsic Viscosity (dl/g)	Viscosity Average Molecular Weight
0	5.01	3.42×10^5
3 to 3.4	1.79	8.0×10^4
6 to 6.7	1.30	5.1×10^4

*Irradiation temperature: 21°C to 40°C

Table II. Effect of Gamma Radiation on Ply Separation of Wet Fiberboard

Type of Fiberboard	Wet Ply Separation (%)	
	Control	Irradiated*
V2s	0	0
V3s	0	0
V3c	30	100

*6 Mrad at 21°C

Table III. Effect of Gamma Radiation on Puncture

Resistance of Fiberboard

Type of Fiberboard	Puncture Resistance (cm-kg)	Reduction in Puncture Resistance* (%)	
		3 Mrad	6 Mrad
V2s (asphalt)	519	5.8	17.3
V2s	741	12.1	21.5
V3s	443	12.3	21.4
V3c	527	10.5	22.5
Domestic (CF-SW-200)	250	4.6	18.1

*Irradiation temperature of 21°C.

Table IV. Effect of Gamma Radiation on Bursting Strength of Fiberboard

Fiberboard	Bursting Strength[a] (kg/cm²)		Reduction in Bursting Strength (%)[b]			
			3 Mrad		6 Mrad	
	Dry	Wet	Dry	Wet	Dry	Wet
V2s	50	35	12.8	16.0	24.3	28.3
V2s (asphalt)	39	37	6.4	9.6	16.8	18.9
V3s	28	14	8.0	13.3	19.3	14.2
V3c	29	11	0.5	2.6[c]	25.0	17.5
Domestic (CF-SW-200)	12	–[d]	9.8	–[d]	14.9	–[d]

[a]Nonirradiated control

[b]Irradiation at ∠1°C

[c]Increase in bursting strength

[d]Test specimens disintegrated

bursting strength. The relatively small changes in bursting strengths of the V3c fiberboard, irradiated to 3 Mrad and tested in both dry and wet states, may be indicative of reinforcement attributed to the flutes of this type of fiberboard.

Effect of Irradiation Temperature

Puncture Resistance: Table V shows the data for the percent change in puncture resistance of V2s and V3s fiberboards that were electron and gamma irradiated to 1 Mrad, 3 Mrad, and 6 Mrad at irradiation temperatures of 21°C, –30°C, and –80°C. Radiation dose and irradiation temperature had significant effects on puncture resistance of both fiberboards. Compared to the nonirradiated fiberboard, the puncture resistance of the gamma irradiated fiberboard decreased with increasing radiation dose at the three irradiation temperatures. In contrast, the electron radiation improved the puncture resistance of the fiberboard at the three dose levels except for the V2s irradiated to 6 Mrad at 21°C and –30°C and the V3s irradiated to 6 Mrad at 21°C. The plot of percent change in puncture resistance versus radiation dose at the three irradiation temperatures is shown for V3s in Figure 1.

Bursting Strength: Table VI shows the results on the percent change in bursting strength of V2s and V3s fiberboards that were subjected to electron and gamma radiation of 1 Mrad, 3 Mrad, and 6 Mrad at irradiation temperatures of 21°C, –30°C and –80°C. Electron and gamma radiation had almost equal effects in reducing the bursting strengths of the fiberboards at the three irradiation temperatures. The percent reduction in bursting strength decreased with decreasing irradiation temperature at the three dose levels. A greater reduction in bursting strength occurred between 21°C and –30°C than between –30°C and –80°C.

Component Testing of Paperboard

Intrinsic Viscosity: Gamma radiation at 6 Mrad and 21°C irradiation temperature caused a rather severe reduction in the intrinsic viscosity of bleached sulfite paperboard. The intrinsic viscosity of the nonirradiated sample was 2.81 dl/g and 1.99 dl/g for the irradiated sample. The molecular weights were calculated to be 1.5×10^5 and 9.4×10^4, respectively.[5] These data are indicative of the degradation of the cellulose chains when irradiated to 6.4 Mrad.

Table V. Effect of Irradiation Temperature on

Puncture Resistance of Fiberboard

Type SF Fiberboard	Irradiation Conditions: Radiation	Irradiation Conditions: Temperature (°C)	Puncture Resistance[a] (cm-kg)	Percent Change in Puncture Resistance[b]: 1 Mrad	3 Mrad	6 Mrad
V2s	Gamma	21	741	− 6.5	−12.1	−21.5
		−30	728	− 5.0	− 9.0	−13.5
		−80	720	− 2.2	− 1.2	− 5.8
	Electron	21	741	9.4	5.0	− 1.2
		−30	728	3.5	3.7	− 4.8
		−80	720	19.4	14.2	13.4
V3s	Gamma	21	443	− 7.0	−12.3	−21.4
		−30	424	− 2.5	− 6.1	−11.4
		−80	449	− 6.4	− 7.3	−12.0
	Electron	21	443	6.5	1.3	− 5.1
		−30	424	10.0	6.9	4.0
		−80	449	7.7	3.5	0.4

[a]Nonirradiated control

[b]Statistically analyzed at 95% confidence level

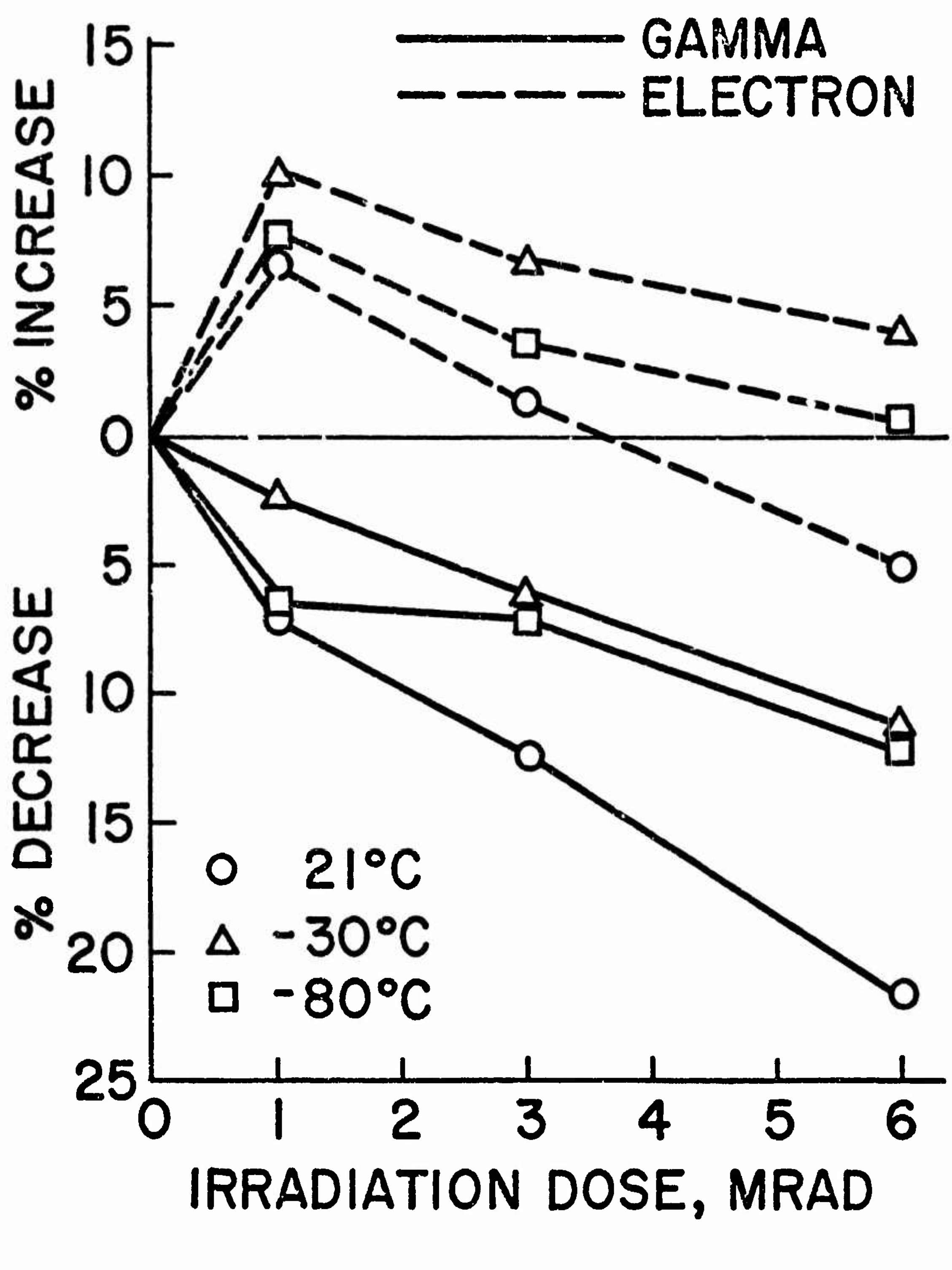

Figure 1. Puncture Resistance of Irradiated Fiberboard.

Table VI. Effect of Radiation and Irradiation Temperature on Bursting Strength of Fiberboard

Type SF Fiberboard	Irradiation Conditions: Radiation	Irradiation Conditions: Temperature (°C)	Bursting Strength[a] (kg/cm²)	Percent Reduction in Bursting Strength[b]: 1 Mrad	3 Mrad	6 Mrad
V2s	Gamma	21	50	9.9	18.5	31.5
		-30	49	4.4	12.1	16.5
		-80	49	2.5	8.3	15.6
	Electron	21	50	5.8	18.0	22.4
		-30	49	5.2	11.5	20.1
		-80	49	3.1	10.6	14.5
V3s	Gamma	21	29	2.1	12.9	21.1
		-30	28	5.2	8.4	14.1
		-80	28	4.8	5.6	11.0
	Electron	21	29	5.4	12.4	19.5
		-30	28	1.0	6.9	11.7
		-80	28	2.4	7.7	11.9

[a]Nonirradiated control

[b]Statistically analyzed at 95% confidence level

Tensile Strength and Tear Resistance: Table VII shows the data on the effect of gamma radiation at two dose levels on tensile strength and tear resistance of the bleached sulfite paperboard. The irradiation temperature was 21°C. At 6.4 Mrad the tensile strength was reduced by 19% and 7% in the machine and cross directions of test, respectively. Tear resistance at this dose level was reduced by 24% and 26% under the same test conditions.

Irradiation Stability of Cellulosic Materials

Two classes of polymeric materials may be distinguished on the basis of irradiation behavior: polymers that crosslink and polymers that degrade. Simultaneous radiation-induced crosslinking and main-chain scission often occur in the polymers. The crosslinking/scission ratio could vary as a function of radiation dose.[14] The principal effects of radiation on the properties of cellulose in an oxygen or nitrogen atmosphere are molecular chain scission, decrease in breaking strength, and increase in reducing groups and carboxyl groups.[7,8,9] During irradiation dehydrogenation reactions occur, and hydrogen, carbon monoxide, and carbon dioxide are evolved.[7] Decrease in absorption and retention of water by irradiated celluloses, as compared with nonirradiated celluloses, was interpreted as evidence for the radiation-initiated formation of intermolecular crosslinking in cellulose.[10,13] Similarly, decrease in moisture regain of cellulose that had been heated to 70°C was attributed to thermal auto-crosslinking through the formation of hemi-acetal and ether bonds.[11,12] It is noteworthy that the literature references report results only for cellulosic materials that were irradiated at ambient temperatures. This paper reports on the gamma irradiation of commercial bleached sulfite paperboard at 21°C and on the electron and gamma irradiation of a variety of fiberboards at 21°C, –30°C and –80°C. The observations of this study show that (a) the sevenfold increase in dose rate of electron radiation at 5×10^9 rads/second compared to the gamma radiation at 8×10^2 rads/second significantly improved the puncture resistance of fiberboard, particularly at 1 Mrad; and (b) less radiation damage occurred in the electron and gamma irradiated fiberboard when the radiation temperature was reduced from 21°C to –30°C or –80°C. This behavior can be interpreted as: The electron radiation at the higher dose rate could produce, through secondary reactions, a large number of free radicals that would result in increased intermolecular bonding or crosslinking of the cellulosic molecules. This could occur when a hydrogen atom is cleaved from a carbon atom of the cellulose. As opposed to recombination with itself, the hydrogen atom could abstract a second hydrogen atom from an adjacent

Table VII. Effect of Gamma Radiation on Tensile Strength and Tear Resistance of Paperboard

Radiation Dose at 21°C in Mrad	Tensile Strength Direction Machine (kg/15 mm width)	Tensile Strength Direction Cross (kg/15 mm width)	Tear Resistance Direction Machine (force in gr to tear)	Tear Resistance Direction Cross (force in gr to tear)
0	37	12	461	651
0.1 to 0.12	35	12	452	593
6.4 to 7.20	30	11	352	485

cellulose molecule, leaving two different cellulose molecules with highly reactive sites.[13] Interaction between these adjacent sites could form an intermolecular bond. The overall effect would be an increase in the crosslinking/scission ratio at the higher dose rate. On the other hand, a reduction in irradiation temperature would lead to not only less crosslinking but also less chain scission because diffusion of free radicals in the solid phase, especially at −30°C or −80°C, would be reduced, and the most probable fate of the free radicals of the cellulose molecules would be recombination.

Drop Test of Gamma Irradiated Fiberboard Boxes

The effect of gamma radiation on the performance of the fiberboard materials was determined by drop testing of nonirradiated and irradiated fiberboard containers filled with twenty 303 x 509 water-filled cans. Results of drop tests are summarized in Table VIII. Figure 2 is a plot of percent reduction in the number of drops to the first scoreline failure versus irradiation dose at 3 Mrad and 6 Mrad. Irradiation temperature was 21°C. The drop heights were selected to achieve a specific type of failure within a reasonable number of drops. The maximum number of drops was 64. Even though 2.5 cm and 15 cm tears were recorded, failure of the fiberboard container was considered to have occurred at either a scoreline tear completely through the material and across its entire length or whenever spillage of contents of the fiberboard container occurred. The strapping of the fiberboard containers aided in extending the number of drops from the failure point of complete scoreline tear to the point of spillage of contents. The V2s fiberboard containers that were water-sprayed after irradiation were less rigid and the flaps of the boxes became very flexible and spongy. Improvement was noted for these fiberboard containers in that the percent reduction in the number of drops to scoreline failure was 43% for the fiberboard containers that were irradiated to 6 Mrad and tested in the dry state compared to a reduction of 38% for the fiberboard containers that were irradiated to the same dose and tested after water spraying. In addition, the V2s fiberboard containers that were irradiated to 3 Mrad and tested after water spraying were equal in performance to the nonirradiated controls. Compared to the nonirradiated fiberboard containers, the irradiated V3c and V3s fiberboard containers that were tested in the dry and "after water spraying" states showed almost equal reductions in the number of drops to reach specific type of damage. These reductions increased with increasing radiation dose. Likewise, Domestic (CF-SW-200) fiberboard containers tested only in the dry state showed reductions in the number of drops with increasing radiation dose.

Table VIII. Effect of Gamma Radiation on Performance of Fiberboard Containers

Type Fiberboard	Conditioning	Radiation Dose (Mrad)	Number of Drops to First [a]: 2.5-cm Tear	15-cm Tear	Scoreline Failure	Spillage
V2s	Dry	0	>64[b]	>64[b]	>64[b]	>64[b]
		3	16.2	45.5	48.6	>64[b]
		6	10.1	21.6	36.0	>64[b]
	Water Spray	0	>64[b]	>64[b]	>64[b]	>64[b]
		3	46.0	56.7	64[b]	64[b]
		6	26.5	34.3	39.5	42.0
V3s	Dry	0	7.3	10.0	20.1	23.8
		3	2.2	4.5	7.8	9.0
		6	1.7	3.2	5.8	7.0
	Water Spray	0	8.8	12.8	21.0	23.0
		3	2.2	4.8	[illegible]	12.2
		6	1.6	4.0	6.7	7.7
V3c	Dry	0	20.0	35.7	42.7	>56.0
		3	9.0	20.0	28.0	35.7
		6	8.0	14.3	20.7	23.7
	Water Spray	0	18.7	42.3	49.3	>56.0
		3	13.5	21.5	25.3	44.3
		6	6.3	11.0	18.3	22.9
Domestic (CF-SW-200)	Dry	0	2.8	6.3	10.4	15.2
		3	2.3	5.0	7.3	9.0
		6	1.0	–	3.0	4.8

[a] Average of 6 fiberboard containers

[b] No failure at 64 drops

Performance of Fiberboard and Paperboard Boxes in the Shipment and Storage of Radappertized Beef

The tinplate cans of beef were packed for shipment in fiberboard containers (Domestic 200CF-SW) equipped with liners, pads, and partitions. The flexible packages of beef were packed in paperboard containers which, in turn, were packed in the fiberboard containers. The tinplate cans were retained in the shipping containers during the gamma radiation processing. Likewise, the flexible packages were retained in the paperboard boxes during electron radiation processing. Prior to irradiation processing at 4.7 to 7.1 Mrad, the containers of beef were shipped 1,200 miles via truck in the frozen state. The temperature during irradiation was –30°C. After the irradiation processing, the containers of beef were shipped 1,000 miles via truck in the nonfrozen state at ambient temperature. Inspection of the shipping containers after one year of storage showed that irradiation processing in the frozen state and subsequent shipment and storage of the containers of irradiation sterilized beef did not seriously impair the functional performance of the fiberboard and paperboard containers for packing of cans and flexible packages of irradiation sterilized beef.

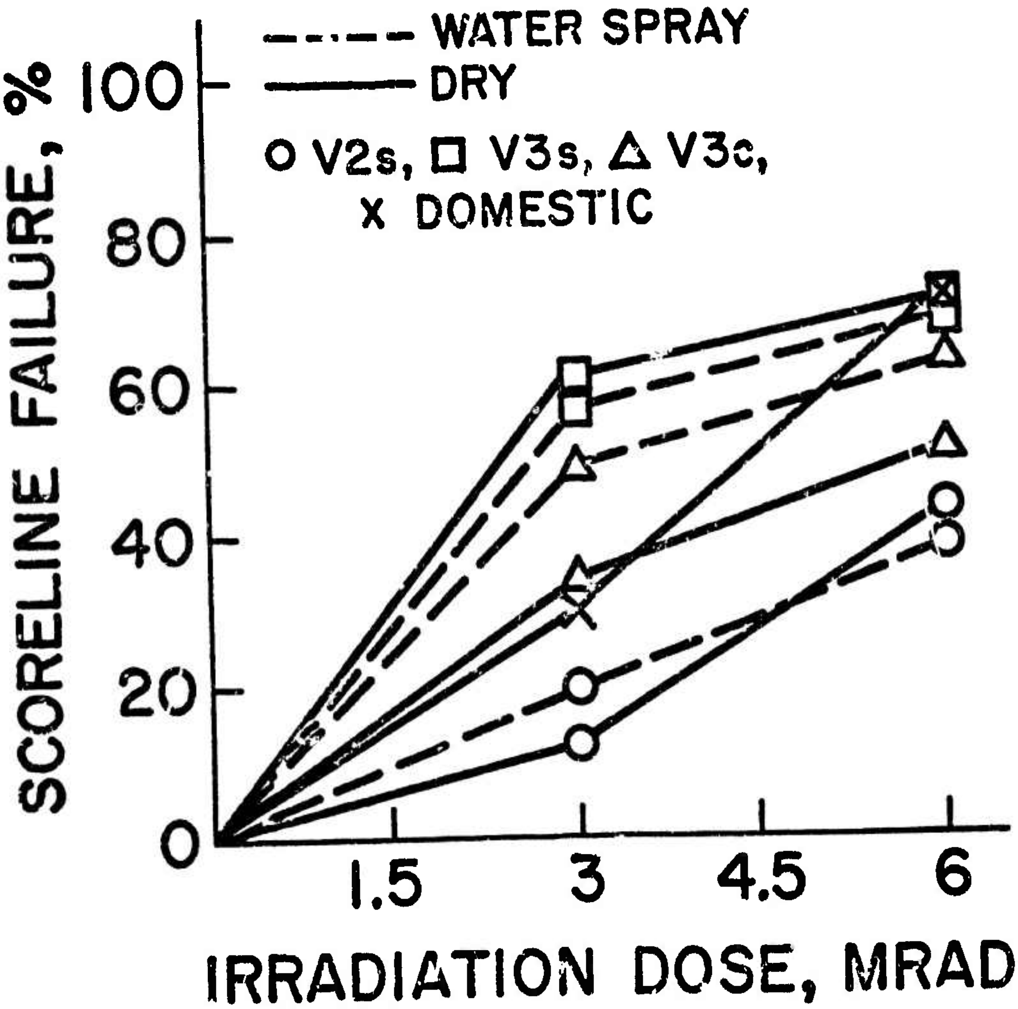

Figure 2. Scoreline Failure of Irradiated Fiberboard.

Conclusions

Electron and gamma irradiation of four types of fiberboard (V2s, V3s, V3c, and Domestic CF-SW-200) at 21°C, –30°C and –80°C, and one paperboard material (bleached sulfite) at 21°C, caused rather severe reduction in the values of selected chemical and physical properties. In general, the bursting strength and puncture resistance of fiberboard was observed to decrease with increasing radiation dosage (1, 3 and 6 Mrad) and increasing irradiation temperature (–80°C, –30°C, 21°C). One exception was found to this general behavior in that the puncture resistance of fiberboard that was electron-irradiated at 1 and 3 Mrad increased significantly at each irradiation temperature; the most pronounced increase in puncture resistance was at 1 Mrad.

Drop testing data showed also that irradiation to 6 Mrad at 21°C caused a marked reduction in the performance of fiberboard containers filled with metal cans. For example, V2s, fiberboard containers that were irradiated and then subjected to standard and water-spray conditioning decreased 43% and 38%, respectively, in the number of drops to scoreline failure.

Even though electron and gamma radiation at food-sterilization doses caused significant loss in strength properties of the paperboard and fiberboard materials, shipping and handling tests showed that these changes were not great enough to seriously impair the functional performance of the paperboard and fiberboard containers for packing of cans and flexible packages of food during the irradiation processing and subsequent shipment and storage.

Experimental

Irradiation Conditions

The electron and gamma (cobalt-60) radiation facilities and the calibration of these sources were described by Holm and Jarrett.[3] Irradiation temperatures were 21°C, –30°C, and –80°C. All samples were conditioned at 23°C and 50% RH for 48 hours before exposure to radiation. In addition, the samples irradiated at –30°C and –80°C were held at these temperatures for 24 hours before irradiation. The gamma source was calibrated with the ferrous-sulfate/cupric-sulfate dosimeter and the electron source by water calorimetry. Dose rates for the gamma and electron sources were 8×10^2 rads/second and 2×10^9 to 5×10^9 rads/second, respectively.

Materials

The fiberboard materials used in this study were V2s weather-resistant solid fiberboard, V3s weather-resistant solid fiberboard, V3c weather-resistant fiberboard with C-flute corrugating medium, and CF-SW-200 Domestic board. Each material was fabricated to conform to Federal Specification PPP-F-320, Fiberboard, Corrugated and Solid, Sheet Stock (Container Grade), and Cut Shapes. The paperboard was a solid bleached sulfite cylinder board (0.07 cm thick).

Containers

The fiberboard containers were constructed in accordance with style RSC of Federal Specification PPP-B-636, Boxes, Shipping, Fiberboard. All fiberboard containers had the bottom flaps and manufacturer's joints stapled with 0.25 cm by 0.05 cm staples with 1 cm crowns and the top flaps were fastened with tape in accordance with Federal Specification PPP-T-76, Tape, Pressure Sensitive, Adhesive Paper, (for Carton Sealing). The containers for the drop tests were filled with twenty 303 x 509 tinplate cans filled with water. Approximate weight of each container of cans was 11.4 kg. All the containers except the Domestic fiberboard containers were reinforced with 1 cm x 0.04 metal strapping one lengthwise encircling the top, bottom, and ends, and one girthwise encircling the top, bottom and sides.

Testing Procedures

Intrinsic Viscosity: The intrinsic viscosity was determined in accordance with TAPPI: T230, Cupriethylenediamine Disperse Viscosity of Pulp. A weighed sample of the fiberboard or paperboard was dissolved in 0.5 molar cupriethylenediamine hydroxide solution. Insoluble matter was removed by filtration and a correction was made to establish the true concentration of the solution. The viscosities were measured in an Oswald-Fenske viscometer at 25°C. Plots of natural log of relative viscosity versus concentration were extrapolated to zero concentration to yield the intrinsic viscosity in deciliters per gram. The molecular weight was calculated from the relationship between intrinsic viscosity and viscosity-average molecular weight,[5] i.e., $(n) = 5.9 \times 10^{-4} \bar{M}_v 0.71$.

Ply Separation: Ten 10 cm x 25 cm samples of each type of fiberboard were totally immersed in fresh clean tap water at 23°C for 24 hours. The samples were removed and immediately tested for ply separation in accordance with Federal Specification PPP-F-320, Fiberboard, Corrugated and Solid Sheet Stock (Container Grade), and Cut Shapes.

Bursting Strength: The test for bursting strength was performed in accordance with TAPPI: T810, Bursting Strength of Corrugated and Solid Fiberboard. Five samples of each type of fiberboard were conditioned at 23°C, 50% RH, for 48 hours for the bursting strength test in the dry state. Six bursts were made through each sample with an equal number of bursts being made from alternate sides of the fiberboard. For wet burst tests, five samples of each fiberboard material were conditioned by total immersion in fresh clean tap water at 23°C for 24 hours. Each sample was removed, excess surface water drained off, and tested as described for the dry samples.

Puncture Resistance: The test for puncture resistance was performed in both the dry and wet states in accordance with TAPPI: T803, Puncture and Stiffness Test of Container Board. Twenty replicate samples were tested for each fiberboard. Conditioning of fiberboard and the preparation of the fiberboard for the tests in the wet state were performed in the same manner as described for the bursting strength tests.

Tensile Strength and Tear Strength of Paperboard: Tensile strength testing was performed in accordance with TAPPI: T404, Tensile Breaking Strength of Paper and

Paperboard, and tear strength in accordance with TAPPI: T414, Internal Tearing Resistance of Paper. Conditioning for both tests was in accordance with TAPPI: T402, Conditioning Paper and Paperboard for Testing.

Fiberboard Container Evaluation: Filled containers style RSC, of each type of fiberboard were subjected to diagonally opposite corner drop tests in accordance with TAPPI: T802, Drop Tests for Fiberboard Shipping Containers. Six containers of each type of fiberboard were used for the drop tests. Drop heights were 107 cm for the V2s and V3s containers, 76 cm for the V3c containers and 46 cm for the Domestic containers. Prior to testing, the containers were conditioned by one of the following procedures:

(a) Standard Conditions. 48 hours at 23°C, 50% RH, and

(b) Sixteen hours of water spray in accordance with TAPPI: T805, Water Resistance of Shipping Containers.

Equipment used for the drop tests was the L.A.B. Drop Tester and the Gaynes Drop Tester. During the drop tests the number of drops to the first 2.5-cm tear, 15-cm tear, complete scoreline tear, and spillage of contents was recorded.

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